

# Recognition of Human Iris Patterns

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# Recognition of Human Iris Patterns

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## Certificate

This is to certify that the work in the thesis entitled ‘Recognition of Human Iris Patterns’ submitted by Animesh Das is an original research work carried out by him under my supervision and guidance for partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering during the session 2011-12 in Department of Computer Science and Engineering, NIT Rourkela.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other University/Institute.

Date -14/05/2012

Rourkela

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## **Abstract**

A biometric system of identification and authentication provides automatic recognition of an individual based on certain unique features or characteristics possessed by that individual. Iris recognition is a biometric identification method that uses pattern recognition on the images of the iris of an individual. Iris recognition is considered as one of the most accurate biometric methods available owing to the unique epigenetic patterns of the iris. In this project, we have developed a system that can recognize human iris patterns and an analysis of the results is done. A hybrid mechanism has been used for implementation of the system. Iris localization is done by amalgamating the Canny Edge Detection scheme and Circular Hough Transform. The iris images are then normalized so as to transform the iris region to have fixed dimensions in order to allow comparisons. Feature encoding has been used to extract the most discriminating features of the iris and is done using a modification of Gabor wavelets. And finally the biometric templates are compared using Hamming Distance which tells us whether the two iris images are same or not.

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# Chapter 1

## Introduction

*Biometric Technology*

*The Human Iris*

*Iris Recognition*

*Objective*

# Chapter 1

## Introduction

### 1.1 Biometric Technology

Biometrics refers to the identification or authentication of an individual based on certain unique features or characteristics. Biometric identifiers are the distinctive and measurable features that is used to label and describe individuals [1]. There are two categories of biometric identifiers namely physiological and behavioural characteristics [2]. Iris, fingerprint, DNA, etc. belong to the former kind of biometric identifiers whereas typing rhythm, gait, voice, etc. belong to the latter.

A biometric system usually functions by first capturing a sample of the feature, such as capturing a digital colour image of a face to be used in facial recognition or a recording a digitized sound signal to be used in voice recognition. The sample may then be refined so that the most discriminating features can be extracted and noises in the sample are reduced. The sample is then transformed into a biometric template using some sort of mathematical function. The biometric template is a normalized and efficient representation of the sample which can be used for comparisons. Biometric systems usually have two modes of operations. An enrolment mode is used for adding new templates into the database and the identification mode is used for comparing a template created for an individual, who wants to be verified, with all the existing templates in the database.

A good biometrics is one which uses a feature that is highly unique. This reduces the chances of any two people having the same characteristics to the minimal. The feature should also be stable so that it does not change over the period of time.

## 1.2 The Human Iris

The iris is a thin circular anatomical structure in the eye. The iris's function is to control the diameter and size of the pupils and hence it controls the amount of light that progresses to the retina. A front view of the iris is shown in Figure 1.1. To control the amount of light entering the eye, the muscles associated with the iris (sphincter and dilator) either expand or contract the centre aperture of the iris known as the pupil.

The iris consists of two layers: the pigmented front fibro vascular called as stroma and beneath it are the pigmented epithelial cells [3]. The stroma is connected to the sphincter muscle which is responsible for the contraction of the pupil and also to the set of dilator muscles, responsible for the enlargement of the pupil which it does by pulling the iris radially [14]. The iris is divided into two basic regions: the pupillary zone, whose edges form the boundary of the pupil and the ciliary zone which constitutes the rest of the iris [3].

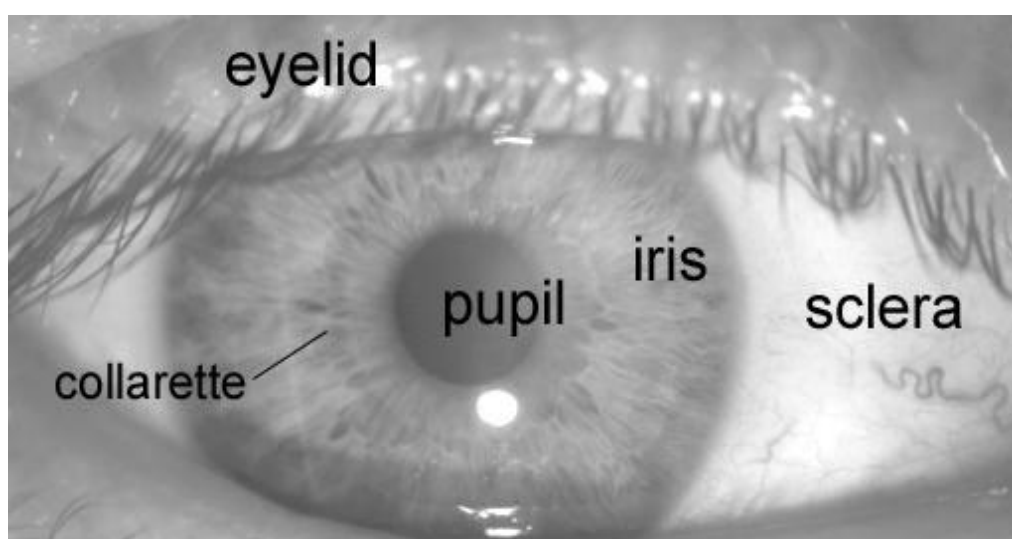


Figure 1.1 – A front view of the Human Iris

### 1.3 Iris Recognition

The iris is a well-protected organ that is externally visible and whose epigenetic patterns are very unique and remain stable throughout most of a person's life [13]. Its high uniqueness and stability makes it a good biometrics that can be used for identifying individuals. These unique patterns can be extracted using image processing techniques employed on a digitized image of the eye and then the results can be encoded into a biometric template which can later be stored in a database for future comparisons. The biometric template is usually created using some sort of mathematical operations. If an individual wants to be identified by the system, then first a digitized image of their eye is first produced, and then a biometric template is created for their iris region. This biometric template is compared with all the other pre-existing templates in the database using certain matching algorithms in order to get the identification of the individual.

Although prototype systems of an iris recognition model had been proposed earlier, it was only in the 1990's that Professor John Daugman (University of Cambridge) implemented a working model [4] [5]. The Daugmans system is patented and has been licensed to many commercial developers of the iris recognition system. Though the Daugman system has been the most popular and successful system known, there are many other efficient systems that have been developed. The most notable of them are Wildes et al. [6], Boles and Boashash [7], Lim et al. [8] and Noh et al. [9].

A large number of studies have tested the Daugman system and all have reported a failure rate of zero. It's claimed that the Daugman system can identify an individual perfectly from a million possibilities. The Wildes et al. system also has a flawless performance [6], whereas the Lim et al. system achieves an accuracy rate of 98.4 % [8].

Iris recognition can be considered as one of the most reliable and accurate method of biometric technology when compared with other biometric technologies such as face, fingerprint and speech recognition [13].

## **1.4 Objective**

The objective of this project is to implement a system that can recognise human iris patterns to be used for biometric identification. The tool that will be used to develop this system will be MATLAB<sup>®</sup>. The projects emphasis will be on creating software that can perform iris recognition instead of hardware components to capture an eye image.

The system will consist of a number of sub-systems, corresponding to each stage of iris recognition. The stages can be classified as segmentation (localizing the iris in an image), normalization (fixed dimensional representation of the iris region) and feature encoding (creating a biometric template by applying certain mathematical operations). The dataset used in this project is the CASIA database [10] which contains a total of 2657 greyscale images.

# Chapter 2

## Segmentation

*Overview*

*Literature Review*

*Implementation*

## **Chapter 2**

### **Segmentation**

#### **2.1 Overview**

The first part of iris recognition is to isolate or localize the actual iris region from the digital eye image. The iris region can be thought of as two circles, one circle forming the iris/sclera boundary and the other forming the iris/pupil boundary. Eyelids and eyelashes are also present which usually cover the upper and lower parts of the iris region. Specular reflections can also occur inside the iris region which may corrupt the iris pattern. So the technique used must be able to exclude these noises and localize the circular iris region.

The degree to which the segmentation applied succeeds will greatly depend on the data set being used. Images where specular reflection occurs can hamper the process of segmentation. If the eyelids and eyelashes cover too much of the iris region then the segmentation process may not result in a success. The segmentation process is very critical as data that has been localized incorrectly will result in very poor recognition rates.

#### **2.2 Literature Review**

##### **2.2.1 Daugman's Integro-differential Operator**

This method was proposed by Daugman in order to localize the iris region [5]. The operator assumes the pupil and limbus region to be circular contours and it performs circular edge detection. The upper and lower eyelids are also detected using the Integro-differential

operator by changing the contour search to a designed arcuate from circular. The Integro-differential operator is defined as [5]:

$$\max(r, x_0, y_0) \left| G_\sigma(r) \times \frac{\partial}{\partial r} \oint_{r, x_0, y_0} \frac{I(x, y)}{2\pi r} ds \right|$$

Where  $I(x, y)$  is the input eye image,  $r$  being the radius that is to be searched for,  $G_\sigma$  is a Gaussian function used for smoothing and  $s$  is the circle contour given by  $r, x_0$  and  $y_0$ . The operator makes a pixel-wise search through the input image and obtains the partial derivative (blurred) of the integral over circular contours that have been normalized in different contours. The boundaries of the pupil and the limbus are supposed to make the contour integral derivative maximum, the point where there will be a sudden change in the values of intensity over the circular borders.

### 2.2.2 Hough Transform

Hough transform is a standard image processing technique and analysis tool that is used for finding curves and shapes that can be represented in a parametric form such as lines, circles and polynomials. The recognition of some global pattern is achieved by using the local patterns. For example, a circle can be detected in an image by using the strong edges in an image as local patterns and searching for circular Hough transform's maximum value.

Wildes et al. make use of this technique to localize irises [6]. The localization method is also based on the first derivative of the image just like Daugman's method. In the method that was proposed by Wildes et al. an edge map is obtained first by thresholding the image intensity gradient's magnitude:

$$|\nabla G(x, y) \times I(x, y)|$$



Where  $\nabla \equiv (\frac{\partial}{\partial x}, \frac{\partial}{\partial y})$  and  $G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x-x_0)^2 + (y-y_0)^2}{2\sigma^2}}$ .  $G(x, y)$  is a Gaussian function used for smoothing with the scalar parameter  $\sigma$  which is used to select the proper scale. A voting process is then used on the edge map to maximize the Hough transform defined for the contour desired. Taking the obtained edge points as  $(x_j, y_j), j = 1, 2, \dots, n$  a Hough transform can be written as:

$$H(x_c, y_c, r) = \sum_{j=1}^n h(x_j, y_j, x_c, y_c, r)$$

Where

$$h(x_j, y_j, x_c, y_c, r) = \begin{cases} 1, & \text{if } g(x_j, y_j, x_c, y_c, r) = 0 \\ 0, & \text{otherwise} \end{cases}$$

The limbus and pupil are modelled as circles. The parametric function  $g$  is defined as:

$$g(x_j, y_j, x_c, y_c, r) = (x_j - x_c)^2 + (y_j - y_c)^2 - r^2$$

Assuming a circle with its centre  $(x_c, y_c)$  and radius  $r$ , the points that fall on the circle result in a zero when evaluated by the function.

### 2.2.3 Active Contour Models

Active contour models have been used by Ritter et al. [11] for localizing the pupil in digitized eye images. They respond to already set internal as well as external forces by either deforming internally or moving around an image until a state of equilibrium is reached. The contour contains some number of vertices, whose positions can be varied by two opposing forces, an internal force, which is dependent on the characteristics desired and an external force, which is dependent on the image. The equation in which each vertex is moved between time  $t$  and  $t+1$  is given as:

$$v_i(t+1) = v_i(t) + F_i(t) + G_i(t)$$

Where  $F_i$  is the internal force,  $G_i$  is the external force and  $v_i$  is the vertex position  $i$ . For localizing the pupil region, the internal forces have to be calibrated such that the contours can form a globally expanding but discrete circle.

## 2.3 Implementation

Of all the various approaches available circular Hough transform was used for localizing the iris. It involves first using canny edge detection on the eye image so as to generate an edge map. The gradients were first biased in the vertical direction so as to detect the outer iris/sclera boundary as had been suggested by Wildes et al. [6]. The horizontal and vertical gradients were weighted equally so as to detect the inner iris/pupil boundary.

To minimize the search range, the range of radius values of images in the CASIA [13] database (which was known beforehand) were set manually. In the CASIA database, the value of the pupil radius ranges from 25 to 75 pixels and that of the iris ranges from 90 to 160 pixels. To make the circle detection process more accurate and efficient, the Hough transform for the outer boundary was performed first and then the Hough transform for the inner boundary was performed, instead of the whole eye since we know that the pupil will always be contained in the iris region. On completion of this process, six parameters are stored, the radius and centre co-ordinates (x,y) of both the circles.

Eyelids were first isolated by fitting a line to both the upper as well as lower eyelid using linear Hough transform. Then a second horizontal line is drawn which intersects the first line at that iris edge which is closest to the pupil. The second horizontal line is used as it allows maximum isolation of the eyelid regions. Canny edge detection was used to create the edge map and the information in the horizontal gradient was only taken. The lines were also

restricted to lie exterior to the pupil region and interior to the iris region. Instead of parabolic Hough transform, the linear version is used since there are fewer parameters to deduce and hence it makes the process less computationally demanding.

For isolating eyelashes as well as specular reflections, a simple thresholding method is used since it is known that eyelashes are generally quite dark in comparison to the rest of the image and specular reflections are usually characterised by high pixel values.

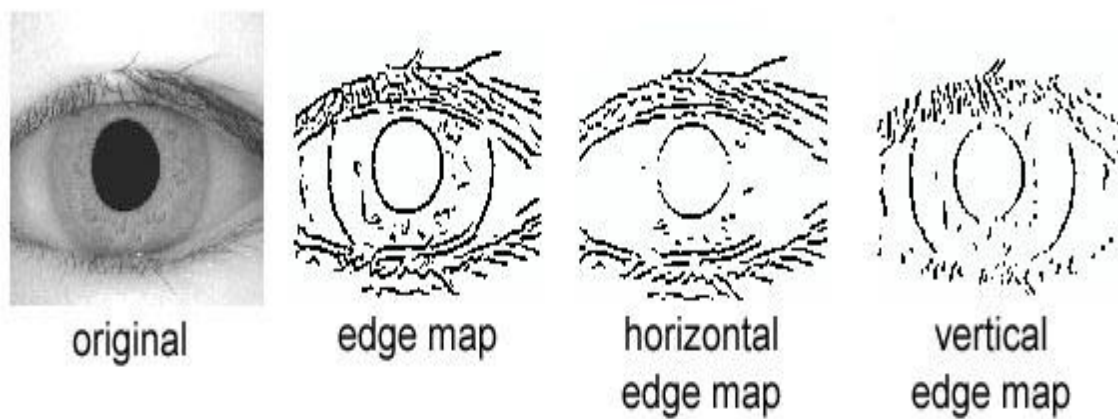


Figure 2.1: Application of canny edge detection on eye image

# Chapter 3

## Normalization

*Overview*

*Literature Review*

*Implementation*

## Chapter 3

### Normalization

#### 3.1 Overview

On having successfully segmented the eye image, the next step is to transform the iris region of the eye image so that it has fixed dimensions in order to allow the feature extraction process to compare two images. Dimensional inconsistencies may arise in eye images mainly due to dilation of the pupil which causes the stretching of the iris. Pupil dilation usually occurs due to varying levels of illumination falling on the eye. The other causes of inconsistency are, varying imaging distance, camera rotation, head tilt, and rotation of the eye within the socket. The normalization process will produce iris regions having constant dimensions such that two images of the same iris taken at different conditions and time will have the same characteristics features at the same locations spatially.

#### 3.2 Literature Review

##### 3.2.1 Daugman's Rubber Sheet Model

Daugman [5] had devised a homogenous rubber sheet model which remapped each point inside the iris region onto a pair of polar co-ordinates  $(r, \theta)$  where  $r$  ranges from  $[0, 1]$  and  $\theta$  ranges from  $[0, 2\pi]$ .

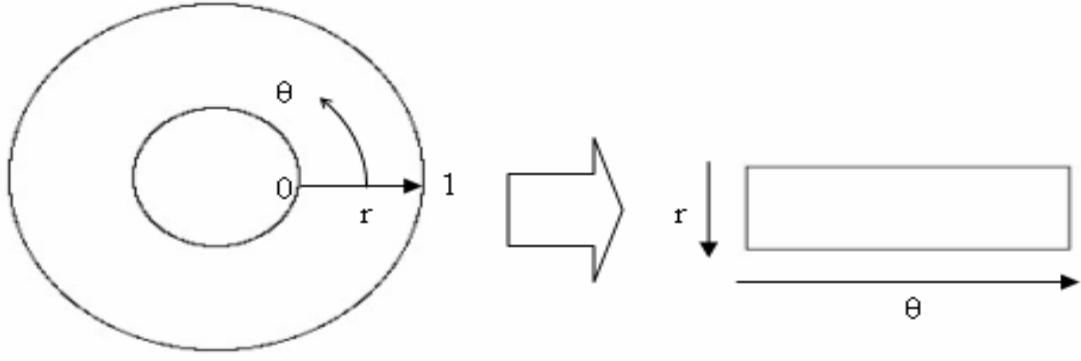


Figure 3.1 – Daugman's rubber sheet model [5]

The Cartesian to polar transform can be written as:

$$x(p, \theta) = (1 - p) \times x_p(\theta) + p \times x_i(\theta)$$

$$y(p, \theta) = (1 - p) \times y_p(\theta) + p \times y_i(\theta)$$

With

$$x_p(\theta) = x_{p^0}(\theta) + r_p \times \cos(\theta)$$

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Where  $I(x, y)$  is the iris image,  $(x, y)$  are the actual Cartesian co-ordinates,  $(r, \theta)$  are their corresponding polar co-ordinates and  $x_p, y_p$  and  $x_i, y_i$  are the co-ordinates of pupil and iris boundaries respectively along the  $\theta$  direction. The rubber sheet model does take into account size inconsistencies and pupil dilation and then produces a normalized pattern representation with fixed and constant dimensions.

### 3.2.2 Image Registration

The Wildes et al. [6] had proposed a technique based on image registration that could be used to normalize iris patterns. This technique geometrically wraps a new image,  $I_a(x, y)$  into aligning with an image in the database,  $I_d(x, y)$ . The alignment process is actually a transformation done by choosing a mapping function,  $(U(x, y), V(x, y))$ . The mapping function should minimize the function:

$$\int_x \int_y (I_d(x, y) - I_a(x - u, y - v))^2 dx dy$$

The alignment process also compensates for the rotational and scale variations. The mapping function is constrained so as to capture a similarity transformation on image co-ordinates  $(x, y)$  to  $(x', y')$ . It is represented as:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} - sR(\emptyset) \begin{pmatrix} x \\ y \end{pmatrix}$$

Where  $s$  is the scaling factor and  $R(\emptyset)$  is a matrix that represents rotation by  $\emptyset$ . The parameters  $s$  and  $\emptyset$  have to be recovered using an iterative minimization process.

### 3.2.3 Virtual Circles

The Boles system [7] uses a method in which the iris images are first scaled so that all images have a constant diameter. Hence while comparing two images, one of the images are chosen as a reference image. This method is different from other methods in the sense that normalization is not done till we are trying to match two images. Once the two irises have been normalized to have constant dimensions features are extracted from the iris region by storing the values of the pixel intensities along virtual concentric circles with the pupil's

centre being the origin. A normalization resolution is done so as to have the same number of data points extracted from each iris.

### 3.3 Implementation

To normalize the iris region a technique similar to Daugman's rubber sheet model was used. The pupil's centre was chosen as the reference point and there are radial vectors that pass through the iris region. Along each radial line, certain numbers of data points are chosen and this is called as the radial resolution. The total number of radial lines that are going around the iris region is called as the angular resolution. Pupils may always not be concentric with the iris. For such situations a remapping formula is used to rescale the points depending on the angle it makes around the circle. This is given by:

$$r' = \sqrt{\alpha\beta} \pm \sqrt{\alpha\beta^2 - \alpha - r_1^2}$$

With

$$\alpha = o_x^2 + o_y^2$$

$$\beta = \cos\left(\pi - \tanh^{-1}\left(\frac{o_x}{o_y}\right) - \theta\right)$$

Where  $r'$  is the distance between the edge of the iris and the edge of the pupil made at an angle an angle  $\theta$ ,  $r_l$  is the radius of the iris and  $o_x, o_y$  are the displacement of the centre of the pupil with respect to the centre of the iris.



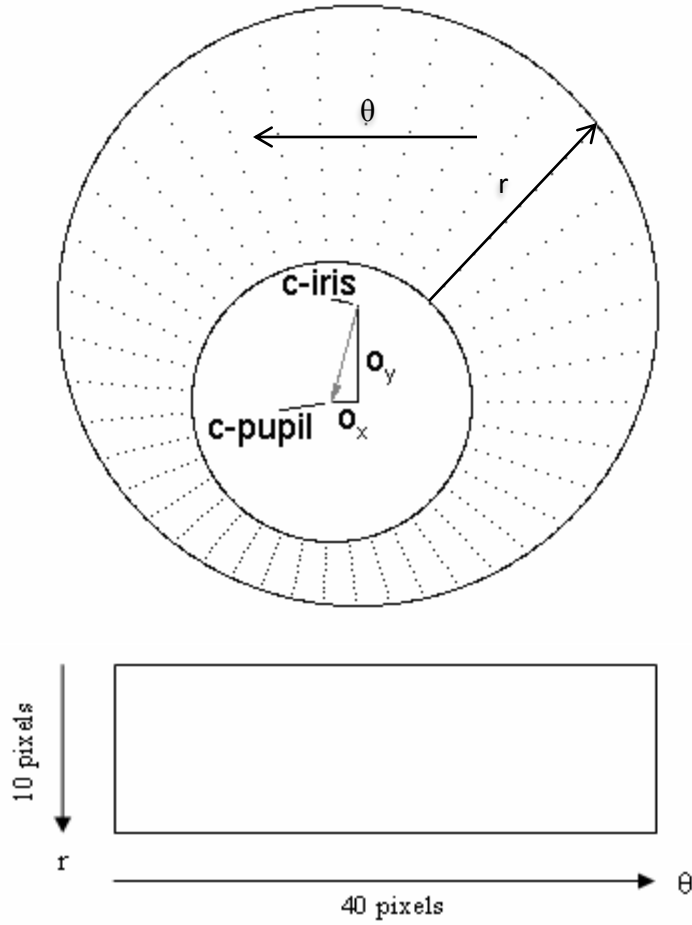


Figure 3.2 – Overview of the normalisation process (with radial resolution taken as 10 pixels and angular resolution taken as 40 pixels).

A definite number of points are to be chosen along each radial line, so that a constant number of radial points are got, irrespective of whether the radius is narrow or wide at some particular angle. The normalized patterns are created by backtracking in which the Cartesian co-ordinates of data points are found out from the angular and radial position present in the normalized pattern. Normalization on the iris region produces a 2D array where the horizontal dimensions represent angular resolution and vertical dimensions represent radial dimensions. A 2D array is also created for marking eyelashes, eyelids and reflections that may have been detected in the segmentation process.

# Chapter 4

## Feature Encoding

*Overview*

*Literature Review*

*Matching*

*Implementation*

## **Chapter 4**

### **Feature Encoding**

#### **4.1 Overview**

To provide for an accurate method of recognition of individuals, the features which are most distinctive in an iris pattern must be extracted. Only these significant parts must be extracted so that they can be encoded into biometric templates which can be used for comparisons. Iris recognition systems usually use band-pass method to decompose an iris image into a biometric template. The biometric templates generated in this process can be compared together using an appropriate matching algorithm.

Wavelets are usually used to decompose the data in an iris image into different components. A number of wavelet filters are applied on the normalized iris region, one for each of the two resolutions with each wavelet being a scaled version of some mathematical operation. The output of convolving the wavelets is encoded into a biometric template which can be used for comparison.

#### **4.2 Literature Review**

##### **4.2.1 Gabor Filter**

A set of Gabor filters which have different frequencies and correspond to different orientations can be used in extracting useful information or features from an image. The

frequency and orientation representation offered by Gabor filters are similar to those in the human visual system, and hence they have been found to be particularly useful in texture representation and discrimination. In the spatial domain, a 2D Gabor filter is actually a sinusoidal plane wave that is modulated by a kernel Gaussian function [16].

Decomposition of a signal is actually done by using a quadrature pair of Gabor filters. The real filter or even symmetric component is specified by a sine wave modulated by a Gaussian function and the imaginary filter or odd symmetric component is specified by a cosine wave modulated by a Gaussian. A 2D Gabor filter applied on an image  $(x, y)$  is represented as [12]:

$$G(x, y) = e^{-\pi[\frac{(x-x_0)^2}{\alpha^2} + \frac{(y-y_0)^2}{\beta^2}]} e^{-2\pi i[u_0(x-x_0) + v_0(y-y_0)]}$$

Where  $(x_0, y_0)$  specify the position of the image,  $(\alpha, \beta)$  specify the effective length and width and  $(u_0, v_0)$  specify modulation with a spatial frequency  $\omega_0 = \sqrt{u_0^2 + v_0^2}$ . The real and imaginary 2D Gabor filters are shown in Figure 4.1.

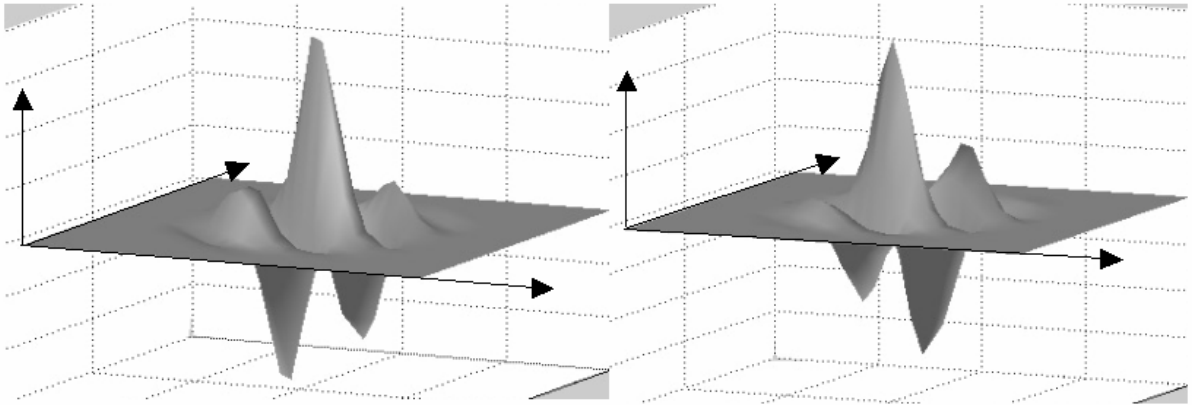


Figure 4.1 – A quadrature pair of Gabor filters.

Daugman [5] had demodulated the output produced by convolving the Gabor filters by quantising the phase information in order to compress the amount of data that was produced. The phase information was quantised into four levels, one for each quadrant in the complex

plane. From this quantised information a biometric template is created which can be used for comparisons. The phase quantisation process can be written as [5]:

$$h_{\{Re,Im\}} = sgn_{\{Re,Im\}} \int_{\rho} \int_{\phi} I(\rho, \phi) e^{-i\omega(\theta_0 - \phi)} e^{-i(r_0 - \rho)^2/\alpha^2} e^{-(\theta_0 - \phi)^2/\beta^2} \rho d\rho d\phi$$

Where  $h_{\{Re,Im\}}$  is a complex valued bit dependent on the sign of the 2D integral and  $I(\rho, \phi)$  is the iris image in polar form.

### 4.2.2 Haar Wavelet

Instead of Gabor wavelets, Lim et al. [8] made use of Haar wavelets to extract features from the eye image. From multi-dimension filtering, a feature vector which consisted of 87 dimensions was computed [8]. As each dimension is real valued with a range from -1.0 to +1.0, the feature vector was sign quantised in which the positive values are represented by 1 and negative values by 0. Lim et al. had compared the use of both Gabor and Haar wavelet and had analysed that the recognition rate with Haar wavelet was 0.9% better than Gabor wavelet [8].

### 4.2.3 Zero crossings of the 1D wavelet

1D wavelets were used by Boles and Boashash [7] to extract features. The wavelet was defined as a second derivative of a smoothing function.

$$\varphi(x) = \frac{d^2\theta(x)}{dx^2}$$

The zero crossings obtained from the dyadic scales of the above filters are used to encode features from the image. The wavelet transform for the signal is given as:

$$W_s f(x) = s^2 \frac{d^2}{dx^2} (f \times \theta_s) \quad \text{Where} \quad \theta_s = (1/s)\theta(x/s)$$

## 4.3 Matching

### Hamming Distance

Hamming distance is used as a matching algorithm to compare two biometric templates. It gives us knowledge of the number of bits that are same in two bit patterns. Upon using hamming distance we are able to decide whether two patterns were generated from the same iris or from different irises.

For comparing the two bit patterns  $X$  and  $Y$ , the hamming distance is defined as the sum of the exclusive-or (XOR) between  $X$  and  $Y$  over  $N$ , the total number of bits present in the bit pattern.

$$HD = \frac{1}{N} \sum_{j=1}^N X_j(XOR)Y_j$$

### 4.4 Implementation

For implementing feature encoding the normalized iris patterns were convolved with 1D Log-Gabor wavelets. One disadvantage with Gabor filters is that there exist some DC components in the even symmetric filter. However when using Log-Gabor filter (a Gabor filter which is Gaussian but on a logarithmic scale) all the DC components are removed. Log-Gabor filters can be represented as:

$$G(f) = e^{\frac{-(\log(f/f_0))^2}{2(\log(\frac{\sigma}{f_0}))^2}}$$

Where  $f_0$  is the centre frequency and  $\sigma$  is the filter bandwidth.

The 2D normalized iris patterns are broken up into a number of 1D signals which are then convolved with the above 1D Gabor wavelets. Each row of the normalized iris pattern is considered as the 1D signal. Here each row corresponds to one circular ring on the iris region.

The output obtained from filtering is then demodulated and phase quantized using Daugman's method [5]. The output is phase quantised to four levels, one for each quadrant in the complex plane and each filter produces two bits of data in each phasor [15]. The output is depicted in grey code. This is done because while going from one quadrant to another only 1 bit will change.

The feature encoding process produces a bitwise biometric template containing information in the form of bits and a noise mask corresponding to the same image which depicts the corrupt areas or noise patterns in the iris and marks those bits in the template. The regions where amplitude is zero are also marked as noises as the phase information obtained from those points are meaningless. The size of the template will depend on the size of the radial resolution, the angular resolution and the number of filters being used. Figure 4.2 gives an illustration of the entire feature encoding process.





# Chapter 5

## Results and Discussion

*Segmentation*

*Normalization*

*Accuracy*

## Chapter 5

### Results and Discussion

#### Segmentation

The automatic model implemented for the segmentation process proved to be quite successful. The images in the CASIA database had been specifically taken for research related to iris recognition and hence the boundaries between the iris, the pupil and the sclera were quite distinctive. The segmentation technique when applied on the CASIA database had a success rate of 80%.

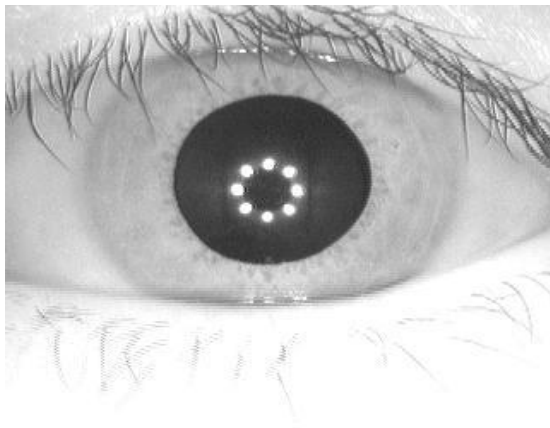


Figure 5.1 – Original Image ‘S1001L01\_0001’

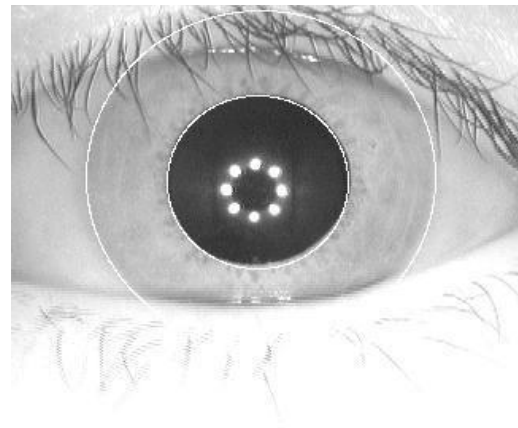


Figure 5.2 – Segmented iris image

(CASIA)[10]

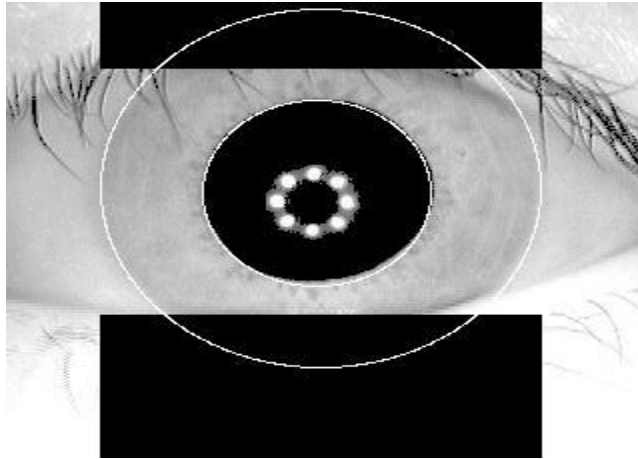


Figure 5.3 – Segmented image with noise detection

There were certain images upon which the segmentation process failed owing to the fact that there was little contrast between pupil and the iris regions and hence canny edge detection failed to find the proper edges.

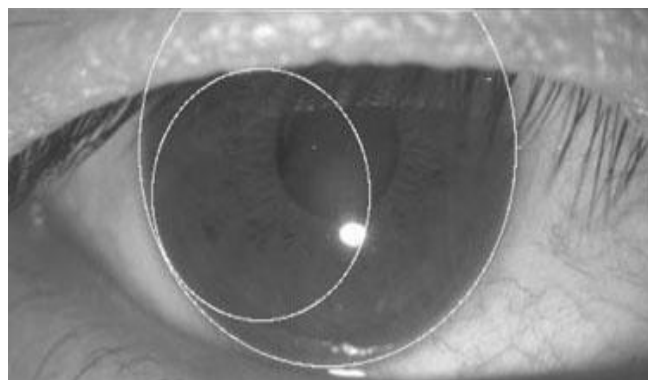


Figure 5.4 – An example where segmentation fails.

## 5.2 Normalization

The normalization process also proved to be quite accurate and some results have been show in the figures that follow. Although the process should have been able to tackle inconsistencies caused in images due to different amounts of pupil dilation, there were some results where the exactly the same pattern was not able to be perfectly constructed of images of the iris taken under different conditions.

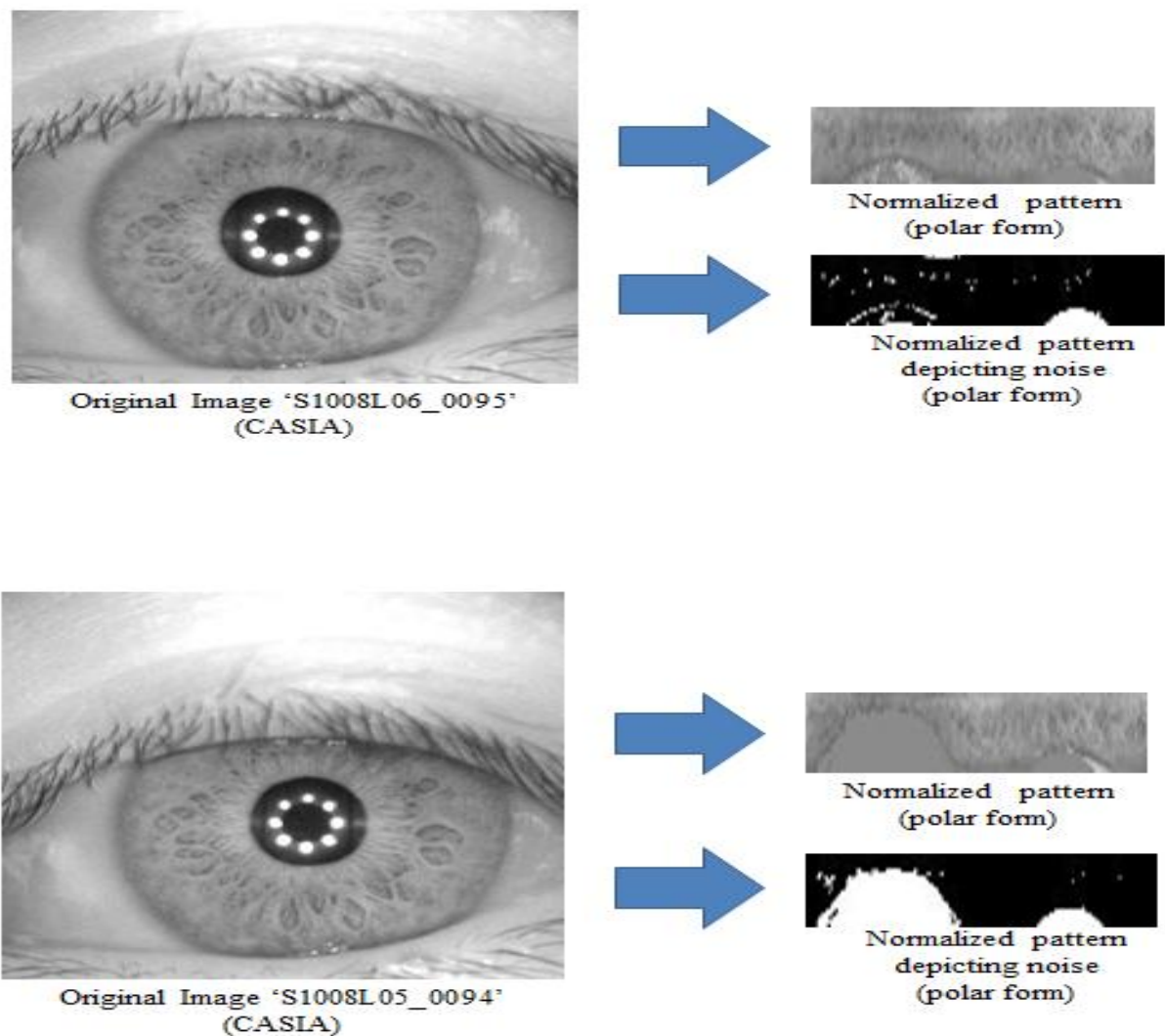


Figure 5.5 –Normalization process on two sample image of the same iris taken in varying conditions

### 5.3 Accuracy

The False Reject Rate (FRR) measures the probability that an individual who has enrolled into the system is not identified by the system. It is also known as Type-I error.

FRR can be calculated as:

$$FRR(n) = \frac{\text{Number of rejected verification attempts for a qualified individual } n}{\text{Total number of verification attempts for that qualified individual } n}$$

And 
$$FRR = \frac{1}{N} \sum_{n=1}^N FRR(n)$$

Where N is the total number of enrolments.

The False Acceptance Rate (FAR) measures the probability that an individual who may have or have not enrolled into the system is identified as another individual. It is also known as a Type-II error.

FAR can be calculated as:

$$FAR(n) = \frac{\text{Number of successful imposter attempts for a qualified individual } n}{\text{Total number of imposter attempts for that qualified individual } n}$$

And 
$$FAR = \frac{1}{N} \sum_{n=1}^N FAR(n)$$

Where N is the total number of enrolments.

From experimental results it is found that the iris recognition has a FRR of 5.26 % and FAR of 4.72 %. The result for FAR/FRR are plotted and shown in figure 5.6.

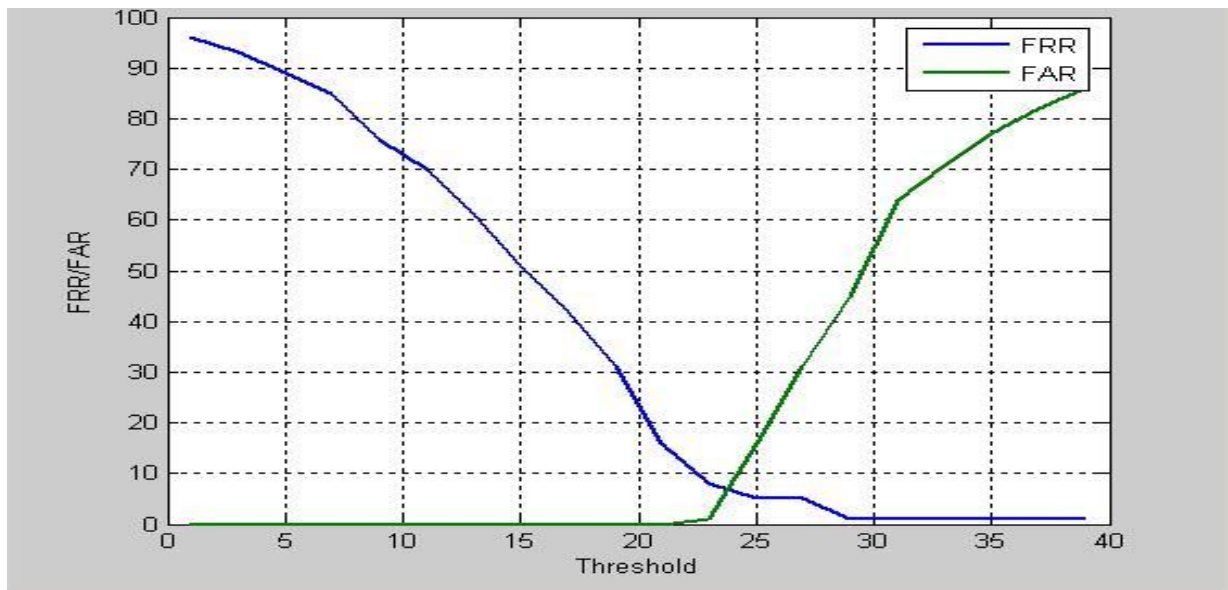


Figure 5.6 – FRR/FAR paired error graph

# **Chapter 6**

## **Conclusion**

## **Chapter 6**

### **Conclusion**

The iris recognition system that was developed proved to be a highly accurate and efficient system that can be used for biometric identification. The project again proved that iris recognition is one of the most reliable methods available today in the biometrics field. The accuracy achieved by the system was very good and can be increased by the use of more stable equipment and conditions in which the iris image is taken. The applications of the iris recognition system are innumerable and have already been deployed at a large number of places that require security or access control.



## References

- [1] Jain, A., Hong, L., & Pankanti, S. "Biometric Identification". Communications of the ACM, 43(2), p. 91-98. DOI 10.1145/328236.328110, 2000.
- [2] Jain, Anil K.; Ross, Arun. "Introduction to Biometrics". Jain, AK; Flynn, P; Ross, A. Handbook of Biometrics. Springer. pp. 1–22. ISBN 978-0-387-71040-2., 2008.
- [3] eye, human."Encyclopædia Britannica" from Encyclopædia Britannica Ultimate Reference Suite DVD, 2006
- [4] J. Daugman. How iris recognition works. Proceedings of 2002 International Conference on Image Processing, Vol. 1, 2002.
- [5] J. Daugman. Biometric personal identification system based on iris analysis. United States Patent, Patent Number: 5,291,560, 1994.
- [6] R. Wildes. Iris recognition: an emerging biometric technology. Proceedings of the IEEE, Vol. 85, No. 9, 1997.
- [7] W. Boles, B. Boashash. A human identification technique using images of the iris and wavelet transform. IEEE Transactions on Signal Processing, Vol. 46, No. 4, 1998.
- [8] S. Lim, K. Lee, O. Byeon, T. Kim. Efficient iris recognition through improvement of feature vector and classifier. ETRI Journal, Vol. 23, No. 2, Korea, 2001.
- [9] S. Noh, K. Pae, C. Lee, J. Kim. Multiresolution independent component analysis for iris identification. The 2002 International Technical Conference on Circuits/Systems, Computers and Communications, Phuket, Thailand, 2002.

- [10] Chinese Academy of Sciences – Institute of Automation. Database of Greyscale Eye Images. <http://www.sinobiometrics.com> Version 1.0, 2003.
- [11] N. Ritter. Location of the pupil-iris border in slit-lamp images of the cornea. Proceedings of the International Conference on Image Analysis and Processing, 1999.
- [12] 3D surface tracking and approximation using Gabor filters, Jesper Juul Henriksen, South Denmark University, March 28, 2007
- [13] S. Sanderson, J. Erbetta. Authentication for secure environments based on iris scanning technology. IEE Colloquium on Visual Biometrics, 2000.
- [14] E. Wolff. Anatomy of the Eye and Orbit. 7th edition. H. K. Lewis & Co. LTD, 1976.
- [15] A. Oppenheim, J. Lim. The importance of phase in signals. Proceedings of the IEEE 69, 529-541, 1981.
- [16] T. Lee. Image representation using 2D Gabor wavelets. IEEE Transactions of Pattern Analysis and Machine Intelligence, Vol. 18, No. 10, 1996.